I. C. 6553 MARCH, 1932

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CRUSHING AND GRINDING LIMESTONE AT THE HOWES CAVE (N. Y.) PLANT OF THE NORTH AMERICAN CEMENT CORPORATION

BY

W. J. FULLERTON AND ALBERT W. COX

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CRUSHING AND GRINDING LIMESTONE AT THE HOWES CAVE (N. Y.) PLANT OF THE NORTH AMERICAN CEMENT CORPORATION[1]

By W. J. Fullerton[2] and Albert W. Cox[3]

INTRODUCTION

This paper is one of a series prepared for the United States Bureau of Mines discussing the methods used in crushing and grinding materials for cement manufacture, and deals particularly with the methods used at the Howes Cave plant of the North American Cement Corporation.

These papers are designed to disseminate technical information regarding the methods used. The cost tabulations represent local operating expenditures only and not total production costs. It is recognized that publication of total production costs might in many instances cause embarrassment to individual producers as well as to the industry as a whole. On the other hand, operating costs are essential to the technical discussion and study of methods employed. The attention of the reader is specifically called to this differentiation in order that no misunderstanding of the scope of the cost tabulations shall ensue.

Crushing and grinding operations are conducted at Howes Cave for the purpose of reducing the material to the high degree of fineness required for the cement raw mix. The present paper deals only with the reduction of the raw material, and will not discuss other stages of the process of manufacturing cement.

The limestone used is of the Manlius and Coeymans formations, is uniformly high in calcium carbonate, and is easy to crush and grind. The clean limestone is crushed in a jaw crusher and hammer mills to minus ¼-inch; at the point of entry to the grinding mills it meets clay and cinders, used as the source of the silica, iron, and alumina required for the cement mix composition. Water is added at the same point, and all grinding is done wet. In the grinding mills the material is reduced in size from minus ¼-inch to 90 per cent minus 200-mesh.

The machines used, materials, and sizes, are indicated in the flow sheet in Figure 1, but a more detailed description is given here.

CRUSHING OPERATIONS

The primary crusher is an Allis-Chalmers jaw crusher, 48 by 60 inches, belt driven by a 200-hp., 440-volt, electric induction motor. The crusher is located in a pit, with its top a little below the level of the quarry floor. In placing cars at the crusher the train is pushed through the crusher building onto the gentle incline beyond. As needed, the cars

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2 One of the consulting engineers, U. S. Bureau of Mines, and engineer, North American Cement Corporation.

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are dropped to the crusher by gravity, and the car to be dumped is stopped at the proper point by a Link-Belt compressed-air car retarder. When in action the plates of this retarder, lying along the inner sides of the rails, are pressed against the flanges of the car wheels and thus act as brakes. The stone is dumped from the side-dump cars by means of a Shephard electric hoist and cable, the offside of the car being hooked and raised.

The stone entering the jaw crusher ranges in size from 4-foot pieces down and is crushed to pass the 9-inch discharge opening.

A Stephens-Adamson apron feeder, 54 inches wide and 15 feet between centers, traveling slowly and driven by a 10-hp. motor, carries the stone from the jaw crusher to the hammer mill.

The hammer mill is situated on the floor of the crusher pit. It is a Pennsylvania hammer mill, No. 802, Super-Thor series, size SXT-13, with 48-inch hammer circle, and is driven directly by a 350-hp. induction motor at 900 r.p.m. It receives minus 9-inch stone and delivers minus 2-inch stone.

The average output, including time running empty, of the jaw crusher and hammer mill, is 117 tons per hour. The capacity of each machine is approximately 200 tons per hour.

A slightly inclined belt-and-bucket elevator, with 40-inch belt and about 60 feet between centers, driven through a Falk speed reducer by a 50-hp. induction motor carries the stone from the hammer mill to a belt conveyor. The buckets are attached to the belt without intervening space and are 36 by 13 by 16 inches in size. The elevator travels at a speed of 163 f.p.m. The conveyor, inclined about 17° from the horizontal, is of 36-inch rubber belt about 210 feet between centers, is driven at 243 f.p.m. through a Falk speed reducer, and carries stone from the elevator to the Hum-mer screens.

The two Hum-mer electric vibrating screens each use two 48 by 60 inch screen sections made of No. 799 Ton-Cap wire with ¼ by ¾ inch openings. They receive the stone from the belt conveyor, passing the fine stone to the four reinforced concrete bins, but sending the retained stone through chutes to two wooden bins and one concrete bin. The fine stone is now minus ¼-inch and is ready for grinding.

The coarse stone is fed by Smidth table feeders to three Williams No. 3 Vulcanite hammer mills, belt driven by 100-hp. electric motors at 1,040 r.p.m. These mills receive minus 2-inch stone and deliver minus ¼-inch stone. They discharge into a 12-inch screw conveyor which in turn delivers to the 12-inch screw that feeds the elevator.

This elevator carries the stone to the 12-inch screw that delivers to the fine-stone bins. The elevator is of the belt-and-bucket type, with 14 by 18 by 8½ inch buckets spaced 24 inches apart on the 14-inch belt. The elevator is 58 feet between centers and travels 226 f.p.m. The fine-stone bins are those already mentioned as receiving the stone passing the Hum-mer screens.

The rate of output of the Williams hammer mills is doubtful, for they do not handle the full tonnage of stone. It is probable that one-fourth is passed directly by the Hum-mer screens and that the Williams mills receive about three-fourths of the total tonnage of stone. On this assumption they crush about 38 tons per machine-hour.

As already mentioned, clay and cinders are added to the stone entering the grinding mills. The proportions must be varied to give the proper balance of lime, silica, iron, and alumina for the cement raw mix, but they will average about as follows: Stone, 85 per cent: clay, 11 per cent; cinders, 4 per cent. This mixture is ground with water from minus ¼-inch to 90 per cent minus 200-mesh.

The stone is removed from the fine-stone bins by two 12-inch screw conveyors, 24 feet and 36 feet long, respectively. Clay is taken from the clay-storage bins by a belt conveyor 22 inches wide and 85 feet between centers. Cinders are transferred from the small cinders bin by a 12-inch screw 12 feet long. The screw conveyors are driven at 65 r.p.m.

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Schaffer automatic scales are used to weigh the stone and clay. Their belts are 20 inches wide and 4 feet 6 inches between centers. The stone scale is above the feeding point of the ball mills and the clay scale is below the clay-storage bins ahead of the belt conveyor just described. A Smidth table feeder regulates the feed of cinders.

The stone, clay, and cinders meet in a 12-inch screw conveyor about 26 feet long, driven at 10½ r.p.m. through a Falk speed reducer by a 15-hp. motor, which feeds the mixture into the two ball mills, the mixture being wet as it enters the mills.

Grinding

The ball mills are Hardinge conical mills, 8 feet in diameter, one 36 inches long, the other 48 inches long between cones. Each is loaded with 44,300 pounds of balls and is driven directly by a 200-hp. electric motor at 17½ r.p.m. Each mill is equipped with a trommel screen made of No. 66 Ton-Cap 12-mesh wire cloth. The oversize from these screens passes to two elevators, whence it is returned to the mills through steel chutes for re-grinding.

The ball mills reduce the material from minus ¼-inch to 90 per cent minus 20-mesh. The water content of the material leaving the mills is about 28 per cent. The average output is 23 tons per machine-hour (on dry basis).

The material leaving the Hardinge mills flows through a nearly horizontal mechanically agitated trough to the tube mills. Six small tube mills and one large tube mill are on a level below the ball mills, so that their feed comes to them by gravity. One large tube mill is located on the same level as the Hardinge ball mills, and the feed to it is through a belt-and-bucket elevator that is fed by gravity.

There are six Abbe trunnion tube mills, center discharge, 5-foot diameter, 21 feet long, charged about three-fourths full with 12,300 pounds of Danish flint pebbles, and driven by 75-hp. induction motors at 25 r.p.m. The two Smidth tube mills, peripheral discharge, 6½-foot diameter and 21 feet long, are each charged from one-fourth to one-third full with 59,175 pounds of ⅞-inch "Manganoid" iron balls. One mill is driven by a 250-hp. and the other by a 300-hp. electric motor. Both tube mills operate at 32 r.p.m.

The tube mills reduce the material from 90 per cent minus 20-mesh to 90 per cent minus 200-mesh. More water is added at the feed end of the mills, so that the slurry leaving the tube mills contains about 32 per cent of moisture. The average output (on dry basis) is about as follows: Abbe mills, 4.7 tons per mill-hour; Smidth mills, 15.4 tons per mill-hour.

The slurry from the tube mills discharges into pits, whence it is pumped by centrifugal pumps to the storage tanks. After mechanical and compressed air agitation and mixing in the tanks, it is fed to the rotary kilns in which it is burned to cement clinker.

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Summary of crushing and grinding practice

Machines	Material treated	Reduction of size	Tons output per machine-hour[1]
1 jaw crusher (48 x 60 in.)	Stone	From 4-foot and less to 9-inch and less	[2]117
1 hammer mill (Penn. SXT-13)	Stone	From 9-inch and less to 2-inch and less	[2]117
3 hammer mills (Wms. No. 3 Vul.)	Stone	From 2-inch and less to ¼-inch and less	[3] 38
2 ball mills (Hardinge 8 ft.)	Stone, clay, cinders	From ¼-inch and less to 90 per cent minus 20-mesh	23
2 tube mills (Smidth 6½ x 21 ft.)	Stone, clay, cinders	From 90 per cent minus 20-mesh to 90 per cent minus 200-mesh	15.4
6 tube mills (Abbe 5 x 21 ft.)	Stone, clay, cinders	From 90 per cent minus 20-mesh to 90 per cent minus 200-mesh	4.7

1 Not including weight of water, where used.
2 Average output, including time running idle. Capacity is about 200 tons per hour.
3 Approximate.

Note: Stone is crushed dry, but mixture of stone (85 per cent), clay (11 per cent), and cinders (4 per cent) is ground wet. Water content in ball mills is about 28 per cent of the total weight of stone, clay, cinders, and water; in tube mills, about 32 per cent.

The discrepancy between the total outputs from the large hammer mill and the three small hammer mills is accounted for by the fact that the small mills operate intermittently 16 hours (two shifts) a day, whereas the large hammer mill runs only 10 hours a day. The average rate of output shown for the small hammer mills is based on the actual number of mill-hours operated, the total tons of stone crushed, and the assumption that one-fourth of the total tonnage is by-passed around the small hammer mills by the Hum-mer screens. The figure of 38 tons per mill-hour for the average output is approximately correct. The three small mills run intermittently, drawing material from the coarse-stone storage bin.

The rate of output for the Hardinge mills and for the tube mills is based on the actual mill-hours run and on the total tons of material ground. The discrepancy between the average rate of output of the small hammer mills and that of the Hardinge mills is explained by the fact that the small hammer mills are run intermittently as needed to maintain the stock of fine stone ahead of the Hardinge mills. The small hammer mills run the same number of shifts as the Hardinge mills.

The eight tube mills have more than sufficient capacity to handle the material from the Hardinge mills, and only enough tube mills are run at one time to handle this material.

This explains the discrepancies between the output of the large hammer mill and the small hammer mills, between the small hammer mills and the Hardinge mills, and between the Hardinge mills and the tube mills, but there is still a discrepancy between the output of

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the tube mills and of the large hammer mill. In explaining this latter discrepancy, details of the output figures for the units are as follows:

				Tons
Large tube mills:	8,680 hours x	15.4	tons per hour =	133,700
Small tube mills:	16,736 hours x	4.7	tons per hour =	78,800
			Total	212,500
Jaw crusher:	1,552 hours x	117	tons per hour =	181,400

The outputs of the tube mills are not recorded for the separate mills as a matter of routine, but have been determined during tests.

The grinding department usually operated two shifts in 24 hours, but for 2 or 3 months out of the year is operated during three shifts. Thus the ratio of two shifts in the grinding department to one at the jaw crusher is not strictly true for a full year's operation, and the output figures are based on operation for the full year 1930.

PERSONNEL IN CRUSHING AND GRINDING DEPARTMENTS

The labor organization and labor consumption are indicated by the following tabulation. The figures are based on two-thirds full operation, for although the cement plant is a 3-kiln plant, only 2 kilns are normally running. The general mill foreman has supervision of these departments.

Labor organization and consumption

Job	Number of men per shift	Number of shifts	Hours per shift	Man-hours per 24 hours
Operating jaw crusher, dumping cars, etc.	1	1	9	9
Operating Pennsylvania hammer mill, oiling, tending chutes, etc.	1	1	9	9
Operating Hardinge ball mills and Williams hammer mills	1	2	8	16
Operating 8 tube mills, pumps, unloading cinders, cars, etc.	1	2	8	16
Clay-bin and clay-belt attendant	1	2	8	16
Repairman	1	1	9	9
Total man-hours per 24 hours	-	-	-	75
Approximate man-hours per ton of material (dry basis)				0.125

The figure of 0.125 man-hours per ton of material (dry basis) is an approximate figure, based on the tabulation that precedes it with its total of 75 man-hours per 24 hours and using a tonnage of 600 tons crushed and ground per 24 hours. This figure is based on 2-shift operation, at which time 2 cement kilns are operated burning 2,000 barrels in 24 hours and using 600 pounds of dry material per barrel. For 3-kiln operation and 3-shifts the man-hours per ton would be slightly less, for the jaw crusher and hammer mill would still operate during only 1 shift.

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CONSUMPTION OF HAMMERS, BALLS, ETC.

The following figures are based on experience for the full year 1930.

Stone crushed, tons 181,400

Manganese-steel hammers used in Pennsylvania SXT-13 mill:

Total hammer sets	3½
Sets per 100,000 tons stone	1.93

Manganese-steel hammers used in Williams No. 3 mills:

Total hammer sets	5½
Sets per 100,000 tons stone	[4] 4.05

Grinding-media consumption

Type of lining plates used in Hardinge mills		Titanite steel
Number of plates used	140	
Cost of plates used	$1,070.69	
Type of lining used in Abbe mills		Adamant silica brick
Pounds brick used	63,002	
Cost of brick used	$ 787.70	
Type of lining used, Smidth mills		Adamant silica brick

No lining used in these mills during 1930

	Ball mills (Hardinge)	Tube mills (Smidth)	Tube mills (Abbe)
Diameter and length of mill	8 by 3 and 4 feet	6½ by 21 feet	5 by 21 feet
Total pounds of balls used in 1930:			
4 and 5 inch forged-steel balls	26,400 [1]	-	-
⅞-inch round iron balls	-	193,217	-
Danish flint pebbles	-	-	81,813
Ball consumption:			
Per mill-hour, pounds	2.87	22.26	4.89
Per ton ground, pounds	0.124	1.442	1.041
Cost of balls per ton ground	-	$0.0575	$0.0110

1 17,000 pounds, 4-inch; 9,400 pounds, 5-inch.

Note: Tonnage figures are on dry basis. Total tons, 212,500, distributed as follows: Stone, 181,400; clay, 23,400; cinders, 7,700.

4 Approximate. Based on assumption that Hum-mer screens passed one-fourth the total tonnage and sent three-fourths to the Williams mills.

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CRUSHING AND GRINDING COST

The cost of crushing 181,400 tons of dry stone in jaw crusher and Pennsylvania hammer mill from minus 4-foot to minus 2-inch during 1930 is as follows:

	Cost per ton
Labor	$0.0192
Supplies	.0258
Electric power	.0076
Total	.0526

The following table gives the cost of crushing dry stone in 3 Williams hammer mills, and of grinding mixture of stone, clay, and cinders in Hardinge ball mills and Smidth and Abbe tube mills (with 32 per cent of water), from minus 2-inch to 90 per cent minus 200-mesh, 181,400 tons of stone, 23,400 tons of clay, 7,700 tons of cinders, 212,500 tons of mixture:

	Cost per ton
Labor	$0.0793
Supplies	.0851
Power	.0826
Total	.2470

Electric power is made in the Company power plant, using boilers operating on waste heat from the cement kilns, but a small quantity is also purchased. The average cost of power per kilowatt-hour, including that generated and purchased, for 1930, was $0.004.

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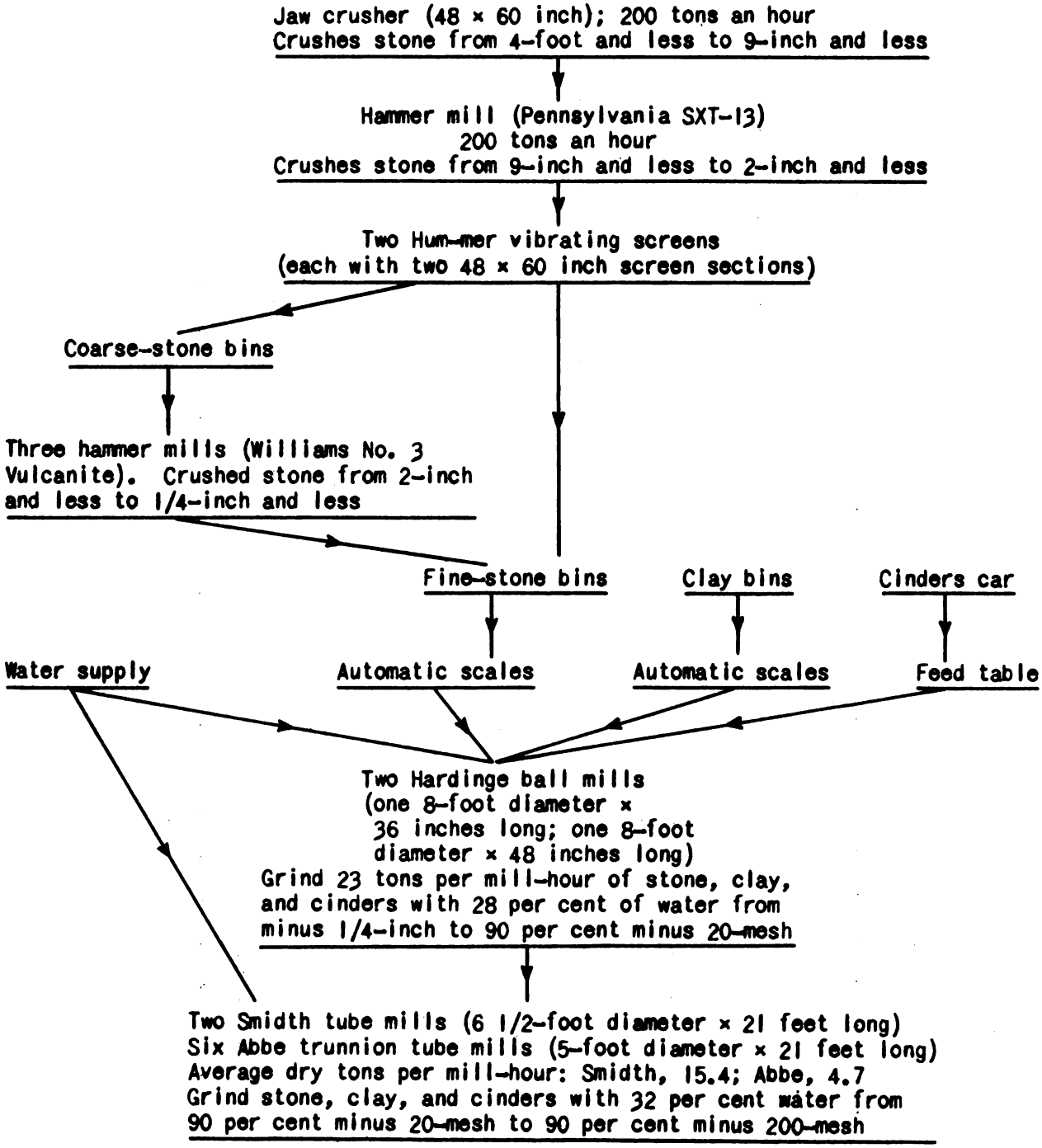
Jaw crusher (48 × 60 inch); 200 tons an hour
Crushes stone from 4-foot and less to 9-inch and less
Hammer mill (Pennsylvania SXT-13)
200 tons an hour
Crushes stone from 9-inch and less to 2-inch and less
Two Hum-mer vibrating screens
(each with two 48 × 60 inch screen sections)
Coarse-stone bins
Three hammer mills (Williams No. 3 Vulcanite). Crushed stone from 2-inch and less to 1/4-inch and less
Fine-stone bins
Clay bins
Cinders car
Water supply
Automatic scales
Automatic scales
Feed table
Two Hardinge ball mills
(one 8-foot diameter × 36 inches long; one 8-foot diameter × 48 inches long)
Grind 23 tons per mill-hour of stone, clay, and cinders with 28 per cent of water from minus 1/4-inch to 90 per cent minus 20-mesh
Two Smidth tube mills (6 1/2-foot diameter × 21 feet long)
Six Abbe trunnion tube mills (5-foot diameter × 21 feet long)
Average dry tons per mill-hour: Smidth, 15.4; Abbe, 4.7
Grind stone, clay, and cinders with 32 per cent water from 90 per cent minus 20-mesh to 90 per cent minus 200-mesh

Figure 1.- Flow sheet showing machines, material, and sizes

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